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PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 16 January 2001 (16.01.01)	
International application No. PCT/GB00/02152	**Applicant's or agent's file reference** P/5678
International filing date (day/month/year) 05 June 2000 (05.06.00)	**Priority date** (day/month/year) 05 June 1999 (05.06.99)
Applicant FISH, Garry, Royston	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

08 December 2000 (08.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Pascal Piriou
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

Form PCT/IB/331 (July 1992)

GB0002152

ENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
P/5678		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 02152	05/06/2000	05/06/1999
Applicant		
VISTEON TECHNOLOGIES, LLC		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[ ] the text is approved as submitted by the applicant.

[X] the text has been established by this Authority to read as follows:

HEAT EXCHANGER TUBE

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 3

[X] as suggested by the applicant.

[ ] None of the figures.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

INTERNATIONAL SEARCH REPORT

Int[redacted]nal Application No
PC[redacted]GB 00/02152

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28F1/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 218 (M-711), 22 June 1988 (1988-06-22) -& JP 63 017393 A (NIPPON DENSO CO LTD), 25 January 1988 (1988-01-25) abstract page 455, column 1, line 30 - line 37; figures ---	1-5,9, 10,12,13
X	WO 98 44305 A (CREARE INC) 8 October 1998 (1998-10-08) page 18, line 14 - line 23; figures ---	14,15
A	US 5 730 213 A (KISER CARL E ET AL) 24 March 1998 (1998-03-24) column 4, line 19 -column 5, line 11; figures 4-9 --- -/--	1-13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2000	22/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mootz, F

1

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/02152

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 165 583 A (HITACHI LTD ;HITACHI CABLE (JP)) 27 December 1985 (1985-12-27) abstract; claims 1-3; figures	1-13
A	US 4 470 452 A (RHODES EUGENE E) 11 September 1984 (1984-09-11) cited in the application abstract; figures	1-13
A	DE 295 09 684 U (BBK BLECHBEARBEITUNG & KOMPONE) 9 November 1995 (1995-11-09) page 6; figures	1-13

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/02152

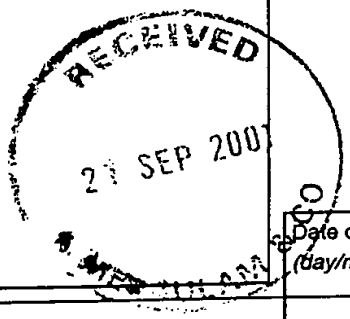
Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 63017393 A	25-01-1988	NONE	
WO 9844305 A	08-10-1998	NONE	
US 5730213 A	24-03-1998	BR 9605545 A	18-08-1998
EP 0165583 A	27-12-1985	JP 1982731 C	25-10-1995
		JP 6100432 B	12-12-1994
		JP 61006595 A	13-01-1986
		DE 3570916 D	13-07-1989
		KR 9004811 B	07-07-1990
		US 4690211 A	01-09-1987
		US 4794775 A	03-01-1989
US 4470452 A	11-09-1984	CA 1192182 A	20-08-1985
DE 29509684 U	09-11-1995	NONE	

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

A. Messulam & Co. Ltd.
43-35 High Road
Bushey Heath
Bushey, Herts WD23 1EE
GRANDE BRETAGNE



PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	19.09.2001
Applicant's or agent's file reference P/5678	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02152	05/06/2000	05/06/1999

Applicant
VISTEON TECHNOLOGIES, LLC et al

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the International application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d	Haase, G

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/5678		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02152	05/06/2000	05/06/1999
International Patent Classification (IPC) or national classification and IPC F28F1/42		
Applicant VISTEON TECHNOLOGIES, LLC et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the International application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08/12/2000	19.09.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d	Authorized officer Duerhammer, M

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02152

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-8,10,11	as originally filed			
9	as received on	07/06/2001	with letter of	01/06/2001

Claims, No.:

1-11	as originally filed			
12-14	as received on	07/06/2001	with letter of	01/06/2001

Drawings, sheets:

1/3-3/3	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-14
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-14
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations
   see separate sheet

Section V,2:

Document JP-A-6301 7393 discloses a tube for conveying coolant through a heat exchanger and a heat exchanger comprising a plurality of such tubes, each tube having a flattened cross-section and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each projection extends across less than 30% of the width of the tube (the drawing clearly shows that the projections have such a diameter that each projection extends less than 30% of the width of the tube).

The device according to claims 1 and 13 differs therefrom in the sense that the area of the tube walls having projections amounts to less than 7,5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible to reduce the resistance to coolant flow through the tubes and to prevent the production of turbulence in the coolant whilst producing the necessary mixing of the coolant under laminar flow conditions.

In document US-A-4470 452 on the contrary the tube is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics. Also in US-A-2017 201 the presence of indentations produces turbulence of the liquid circulating through the tube.

Because the reduction of turbulence by reducing the number of projections to the level mentioned in claims 1 and 13 is not suggested by prior art the subject-matter of these claims fulfils the requirement of Article 33(2)(3) PCT.

The inventive step of method claim 14 is seen in the fact that the projections extend into the internal cross-sectional area of the tube in such an extent that laminar coolant flow is maintained. The laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls which ensures a good mixing of the coolant without disturbing the laminar nature of the flow.

Because this is not suggested by prior art the subject-matter of claim 14 fulfils the

requirement of Article 33(2)(3) PCT.

The dependent claims 2 to 12 contain special embodiments of the subject-matter of claim 1 and fulfil likewise the requirement of Article 33(2)(3) PCT.

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14), wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

15. A method as claimed in Claim 14, wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.

indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and 9 where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is expected that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

5

PATENT COOPERATION TREATY

REC'D 21 SEP 2001
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P/5678		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02152	05/06/2000	05/06/1999
International Patent Classification (IPC) or national classification and IPC F28F1/42		
Applicant VISTEON TECHNOLOGIES, LLC et al		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 2 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08/12/2000	19.09.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Duerhammer, M Telephone No. +49 89 2399 2743

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02152

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-8,10,11	as originally filed			
9	as received on	07/06/2001	with letter of	01/06/2001

Claims, No.:

1-11	as originally filed			
12-14	as received on	07/06/2001	with letter of	01/06/2001

Drawings, sheets:

1/3-3/3	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

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   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-14
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-14
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-14
	No:	Claims	

2. Citations and explanations
   see separate sheet

Section V,2:

Document JP-A-6301 7393 discloses a tube for conveying coolant through a heat exchanger and a heat exchanger comprising a plurality of such tubes, each tube having a flattened cross-section and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each projection extends across less than 30% of the width of the tube (the drawing clearly shows that the projections have such a diameter that each projection extends less than 30% of the width of the tube).

The device according to claims 1 and 13 differs therefrom in the sense that the area of the tube walls having projections amounts to less than 7,5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible to reduce the resistance to coolant flow through the tubes and to prevent the production of turbulence in the coolant whilst producing the necessary mixing of the coolant under laminar flow conditions.

In document US-A-4470 452 on the contrary the tube is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics. Also in US-A-2017 201 the presence of indentations produces turbulence of the liquid circulating through the tube.

Because the reduction of turbulence by reducing the number of projections to the level mentioned in claims 1 and 13 is not suggested by prior art the subject-matter of these claims fulfils the requirement of Article 33(2)(3) PCT.

The inventive step of method claim 14 is seen in the fact that the projections extend into the internal cross-sectional area of the tube in such an extent that laminar coolant flow is maintained. The laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls which ensures a good mixing of the coolant without disturbing the laminar nature of the flow.

Because this is not suggested by prior art the subject-matter of claim 14 fulfils the

requirement of Article 33(2)(3) PCT.

The dependent claims 2 to 12 contain special embodiments of the subject-matter of claim 1 and fulfil likewise the requirement of Article 33(2)(3) PCT.

indentations on the upper (as seen in the figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and S where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is preferable that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14) wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger and wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls..

Tube for conveying coolant through a heat exchanger.

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers, for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

I have now surprisingly found that better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production

of turbulence in the coolant, whilst producing the necessary mixing of the coolant under laminar flow conditions. Mixing means that coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa, this process taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, it was seen necessary to encourage turbulence to achieve this desirable uniform temperature distribution.

In addition to giving good mixing of the hot coolant in the tube, the absence of turbulence in my invention can also reduce the back pressure which the coolant experiences in flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention there is provided a tube for conveying coolant through a heat exchanger, the tube having a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible (in comparison to the prior art) to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant, whilst still obtaining the necessary mixing of the

coolant.

The projections are preferably dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results obtained by the inventor at the time of preparation of this specification are achieved when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy and the tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld, with the weld seam running along one edge of the tube which joins the two major walls, after the tube has been flattened. However, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes is also possible. For example the projections may have a length greater than their width, and in this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be

reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the tube/header tank joint area.

The invention also provides a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins, wherein each of the tubes has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figures 8 and 9 are sections taken on the lines VIII-VIII and IX-IX from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14 and in heat exchange contact with the tubes. In use,

coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16, and the heat of the coolant in the tubes 14 is given up to the air passing through the fins.

Figure 2 shows an enlarged cross sectional view through a tube 14. The tube is formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.

The tube 14 shown in Figure 2 has a smooth internal bore 24. If coolant flows along a tube 14 with a smooth internal bore, the coolant flow along the tube tends to be laminar or streamline flow. In this case there will be a region at the centre of the flow (indicated in dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube, and this region of coolant is therefore insulated from the heat exchange taking place at the tube walls by the body of coolant between the region and the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which does enhance mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28, and whilst passing through the tube will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V-IV,V from Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tube 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with

indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and 9 where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is expected that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection. However since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection whereupon diversion and therefore coolant mixing will take place again.

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally (as shown in Figure 8) and also perpendicularly (as shown in Figure 9) to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

Claims

1. A tube (14) for conveying coolant through a heat exchanger (10), the tube having a flattened cross-section with two major opposing walls and internal projections (30) on the major opposing walls (18,20), the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube and the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls.

2. A tube as claimed in Claim 1, wherein the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to less than 5% of the total area of the tube walls.

4. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to approximately 2.5% of the total area of the tube walls.

5. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of dimples (32) formed in the tube walls (18,20), the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. A tube as claimed in any preceding claim, wherein the projections (30) are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. A tube as claimed in Claim 6, wherein the line of projections (30) on one opposing wall (18) extends in a diagonally opposite direction to the line of projections (30) on the other opposing wall (20).

8. A tube as claimed in Claim 6 or Claim 7, wherein the projections (30) on one opposing wall (18) are greater in number than the projections on the other opposing wall (20), and the projections on the one wall (18) are offset across the width of the tube from the projections on the other opposing wall (20).

9. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of indentations (32) punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. A tube as claimed in any preceding claim, wherein the projections (30) are generally square or rectangular in plan view.

11. A tube as claimed in any preceding claim, wherein the projections (30) have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14), wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

15. A method as claimed in Claim 14, wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.

Abstract

Tube for conveying coolant through a heat exchanger.

Coolant tubes 14 for heat exchangers are formed with projections 30 extending into the tube cross section to interfere with the fluid flow 28 and to ensure mixing of the coolant as it passes through the tubes.

To achieve the necessary degree of mixing without causing the flow to become turbulent and thus to prevent unnecessary back pressure, the area of the tube wall occupied by projections 30 is less than 7.5% of the total area of the tube wall.

Figure 3

Fig. 1

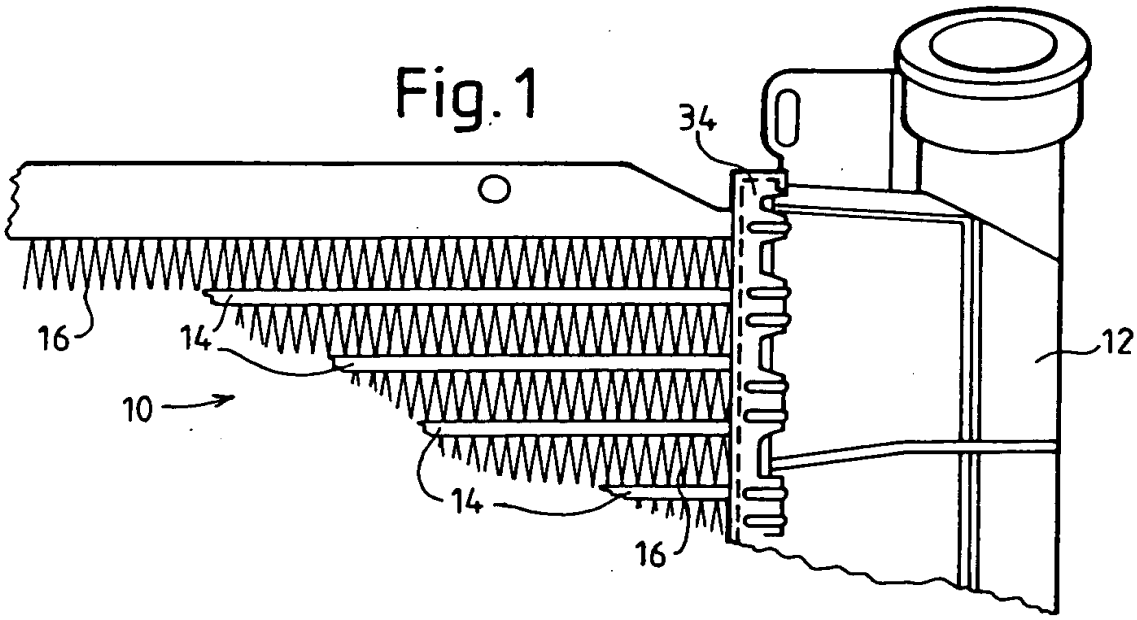
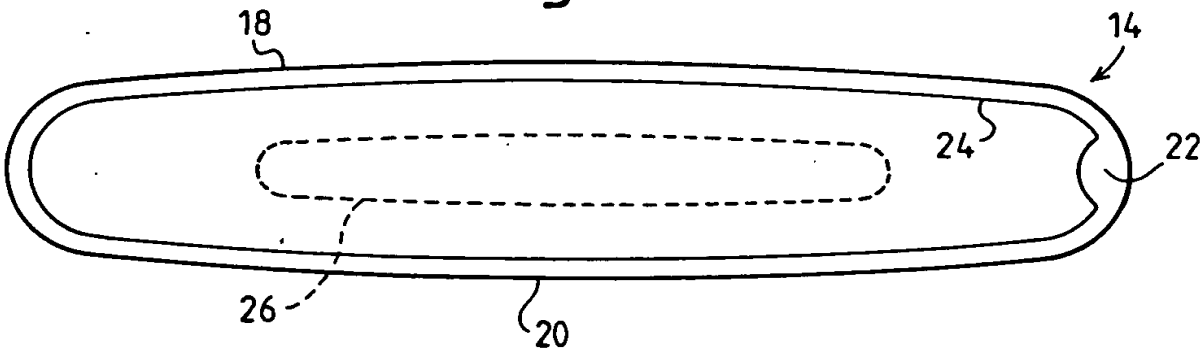


Fig. 2



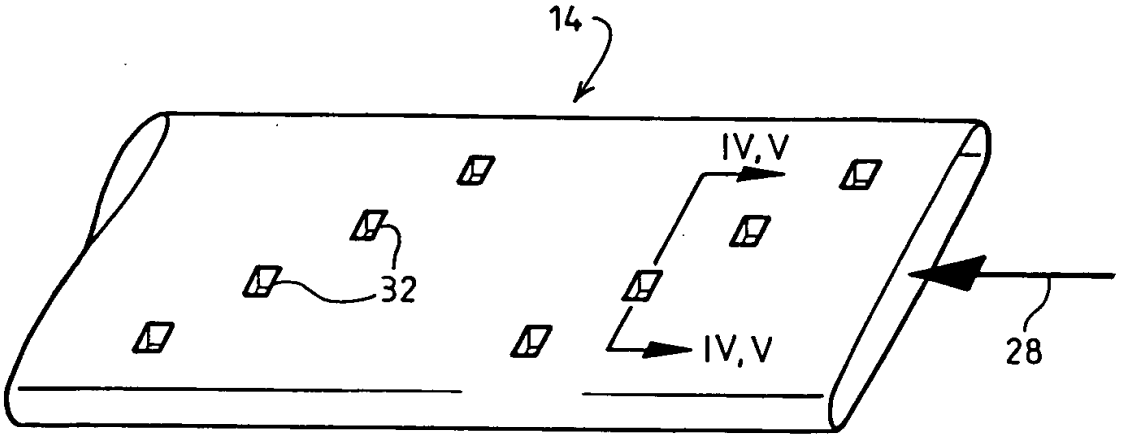
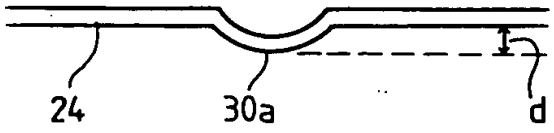


Fig. 3

Fig. 4



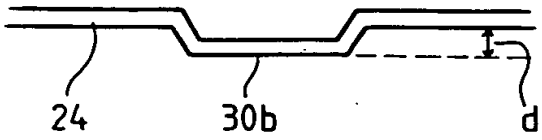


Fig. 5

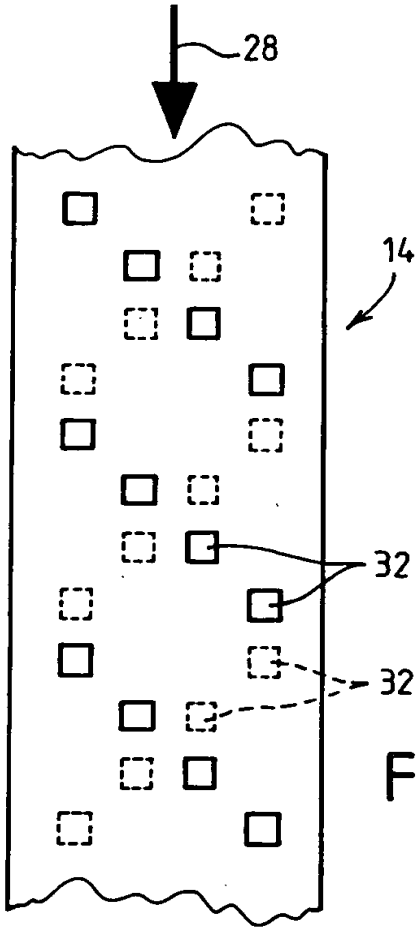


Fig. 6

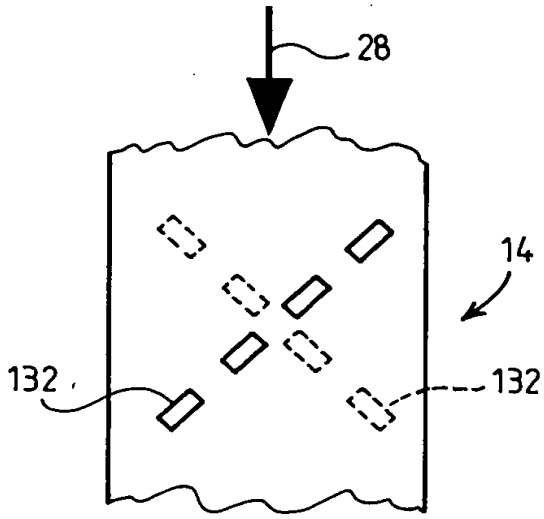


Fig. 7

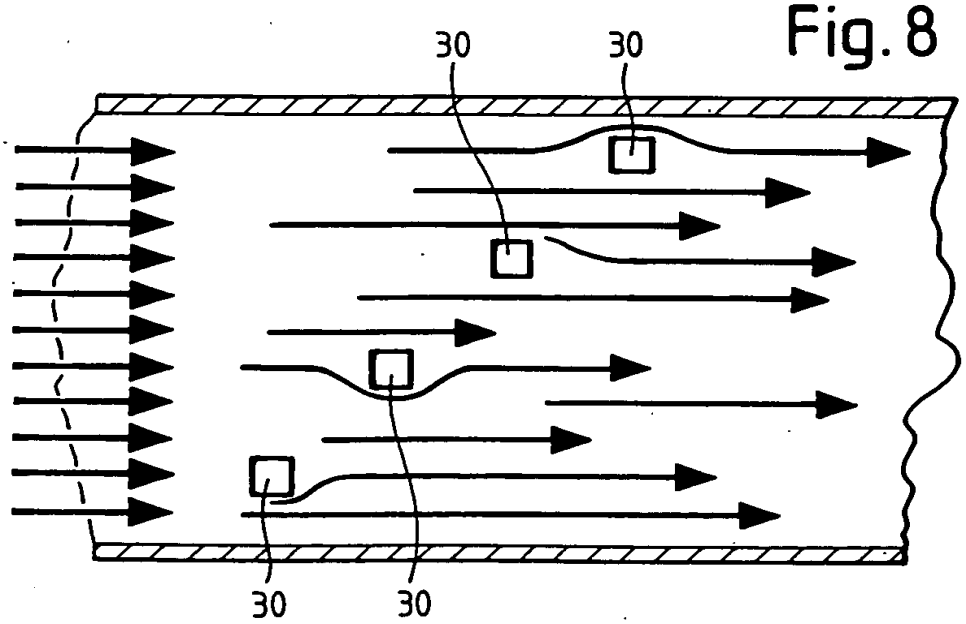


Fig. 8

INTERNATIONAL SEARCH REPORT

Intern tal Application No
PCT/GB 00/02152

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28F1/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 218 (M-711), 22 June 1988 (1988-06-22) -& JP 63 017393 A (NIPPON DENSO CO LTD), 25 January 1988 (1988-01-25) abstract page 455, column 1, line 30 - line 37; figures	1-5,9, 10,12,13
X	WO 98 44305 A (CREARE INC) 8 October 1998 (1998-10-08) page 18, line 14 - line 23; figures	14,15
A	US 5 730 213 A (KISER CARL E ET AL) 24 March 1998 (1998-03-24) column 4, line 19 -column 5, line 11; figures 4-9	1-13

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2000	22/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mootz, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern. nal Application No
PCT/GB 00/02152

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 63017393 A	25-01-1988	NONE	
WO 9844305 A	08-10-1998	NONE	
US 5730213 A	24-03-1998	BR 9605545 A	18-08-1998
EP 0165583 A	27-12-1985	JP 1982731 C	25-10-1995
		JP 6100432 B	12-12-1994
		JP 61006595 A	13-01-1986
		DE 3570916 D	13-07-1989
		KR 9004811 B	07-07-1990
		US 4690211 A	01-09-1987
		US 4794775 A	03-01-1989
US 4470452 A	11-09-1984	CA 1192182 A	20-08-1985
DE 29509684 U	09-11-1995	NONE	

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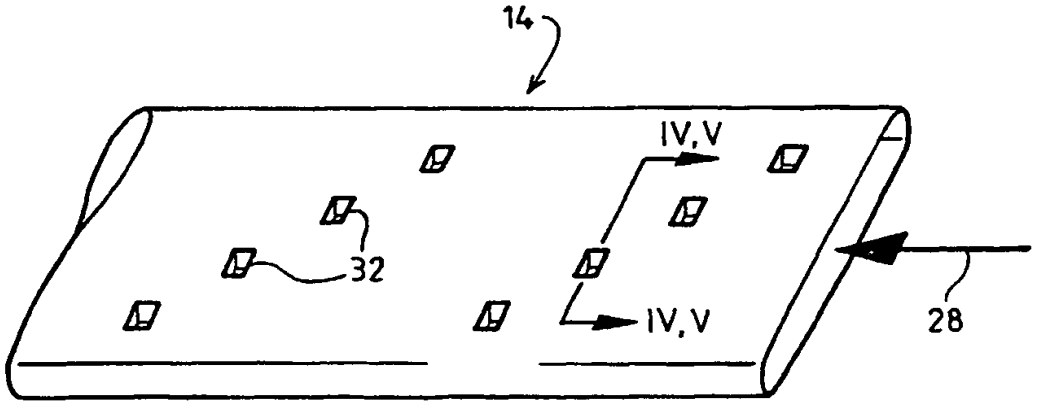
(54) Title: HEAT EXCHANGER TUBE



(57) Abstract: Coolant tubes (14) for heat exchangers are formed with projections (30) extending into the tube cross section to interfere with the fluid flow (28) and to ensure mixing of the coolant as it passes through the tubes. To achieve the necessary degree of mixing without causing the flow to become turbulent and thus to prevent unnecessary back pressure, the area of the tube wall occupied by projections (30) is less than 7.5% of the total area of the tube wall.

WO 00/75593 A1

HEAT EXCHANGER TUBE

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers, for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

I have now surprisingly found that better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production

of turbulence in the coolant, whilst producing the necessary mixing of the coolant under laminar flow conditions. Mixing means that coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa, this process taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, it was seen necessary to encourage turbulence to achieve this desirable uniform temperature distribution.

In addition to giving good mixing of the hot coolant in the tube, the absence of turbulence in my invention can also reduce the back pressure which the coolant experiences in flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention there is provided a tube for conveying coolant through a heat exchanger, the tube having a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible (in comparison to the prior art) to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant, whilst still obtaining the necessary mixing of the

coolant.

The projections are preferably dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results obtained by the inventor at the time of preparation of this specification are achieved when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy and the tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld, with the weld seam running along one edge of the tube which joins the two major walls, after the tube has been flattened. However, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes is also possible. For example the projections may have a length greater than their width, and in this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be

reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the tube/header tank joint area.

The invention also provides a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins, wherein each of the tubes has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figures 8 and 9 are sections taken on the lines VIII-VIII and IX-IX from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14 and in heat exchange contact with the tubes. In use,

coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16, and the heat of the coolant in the tubes 14 is given up to the air passing through the fins.

Figure 2 shows an enlarged cross sectional view through a tube 14. The tube is formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.

The tube 14 shown in Figure 2 has a smooth internal bore 24. If coolant flows along a tube 14 with a smooth internal bore, the coolant flow along the tube tends to be laminar or streamline flow. In this case there will be a region at the centre of the flow (indicated in dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube, and this region of coolant is therefore insulated from the heat exchange taking place at the tube walls by the body of coolant between the region and the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which does enhance mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28, and whilst passing through the tube will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V-IV,V from Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tube 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with

indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and 9 where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is expected that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection. However since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection whereupon diversion and therefore coolant mixing will take place again.

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally (as shown in Figure 8) and also perpendicularly (as shown in Figure 9) to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

Claims

1. A tube (14) for conveying coolant through a heat exchanger (10), the tube having a flattened cross-section with two major opposing walls and internal projections (30) on the major opposing walls (18,20), the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube and the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls.

2. A tube as claimed in Claim 1, wherein the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to less than 5% of the total area of the tube walls.

4. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to approximately 2.5% of the total area of the tube walls.

5. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of dimples (32) formed in the tube walls (18,20), the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. A tube as claimed in any preceding claim, wherein the projections (30) are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. A tube as claimed in Claim 6, wherein the line of projections (30) on one opposing wall (18) extends in a diagonally opposite direction to the line of projections (30) on the other opposing wall (20).

8. A tube as claimed in Claim 6 or Claim 7, wherein the projections (30) on one opposing wall (18) are greater in number than the projections on the other opposing wall (20), and the projections on the one wall (18) are offset across the width of the tube from the projections on the other opposing wall (20).

9. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of indentations (32) punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. A tube as claimed in any preceding claim, wherein the projections (30) are generally square or rectangular in plan view.

11. A tube as claimed in any preceding claim, wherein the projections (30) have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14), wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

15. A method as claimed in Claim 14, wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.

Fig. 1

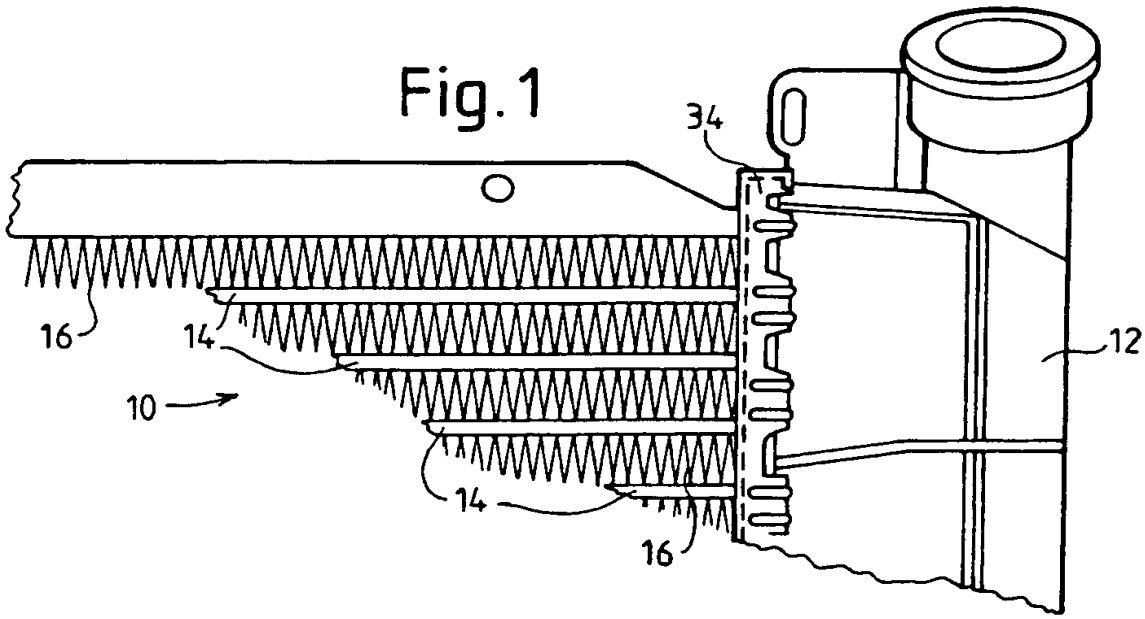
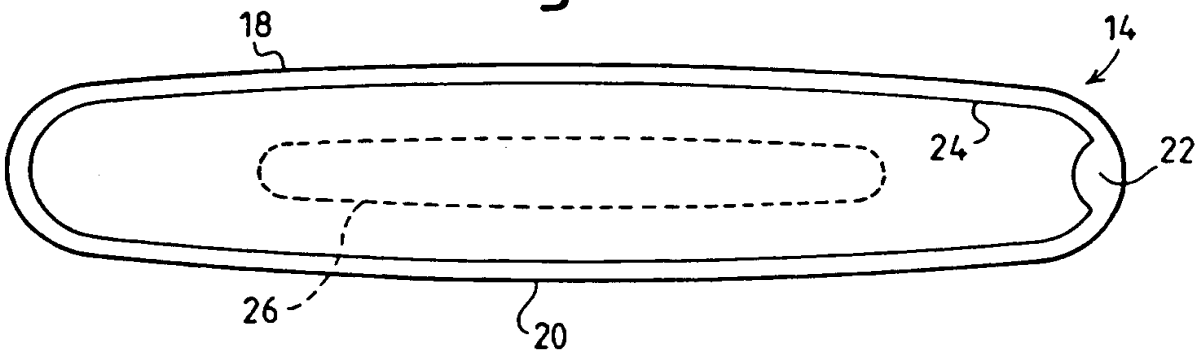


Fig. 2



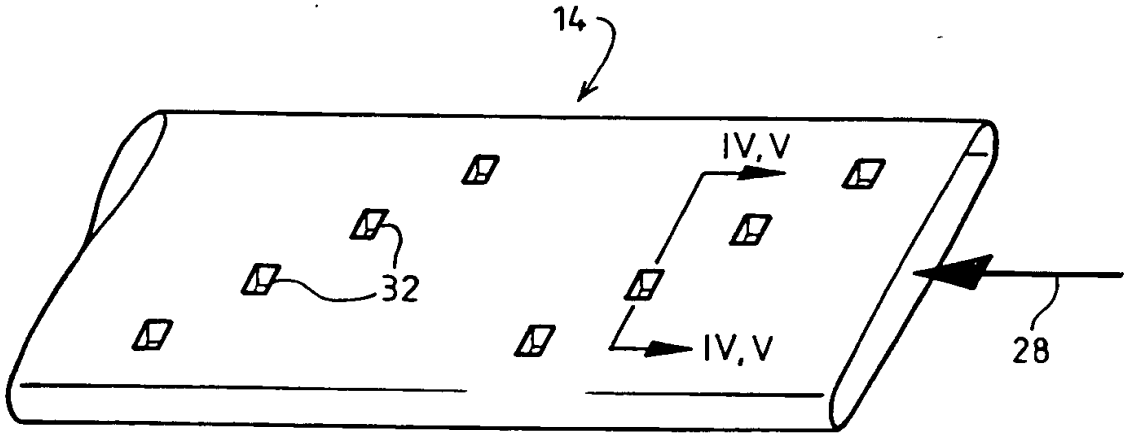
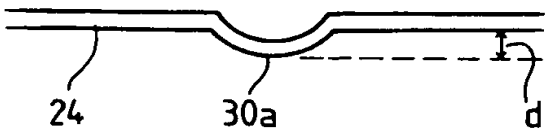


Fig. 3

Fig. 4



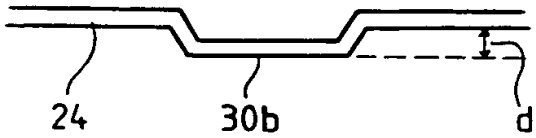


Fig. 5

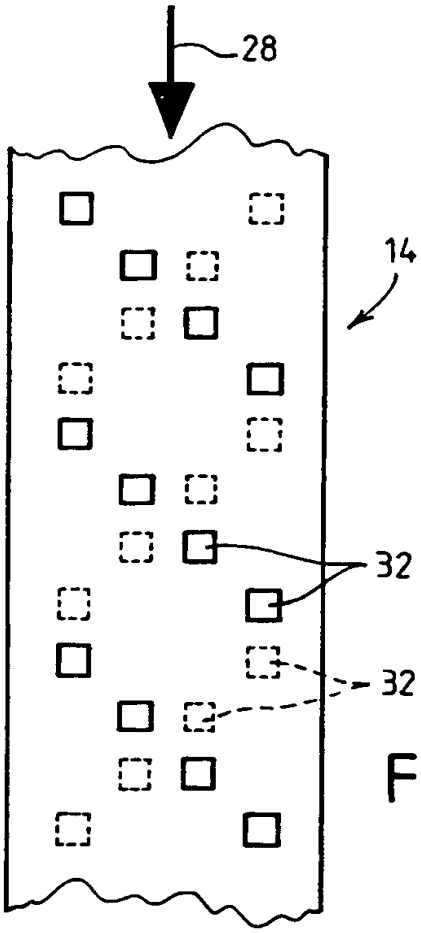


Fig. 6

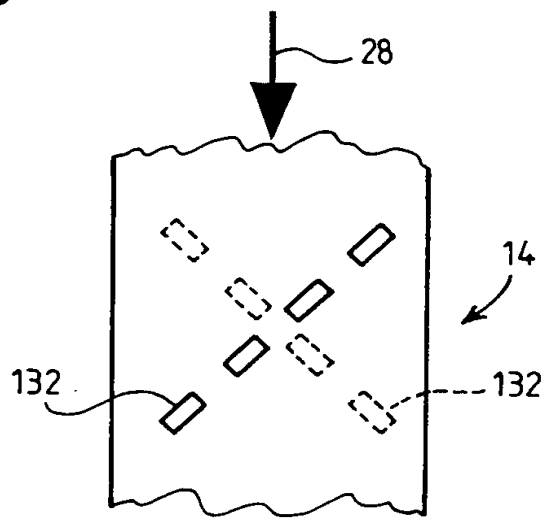
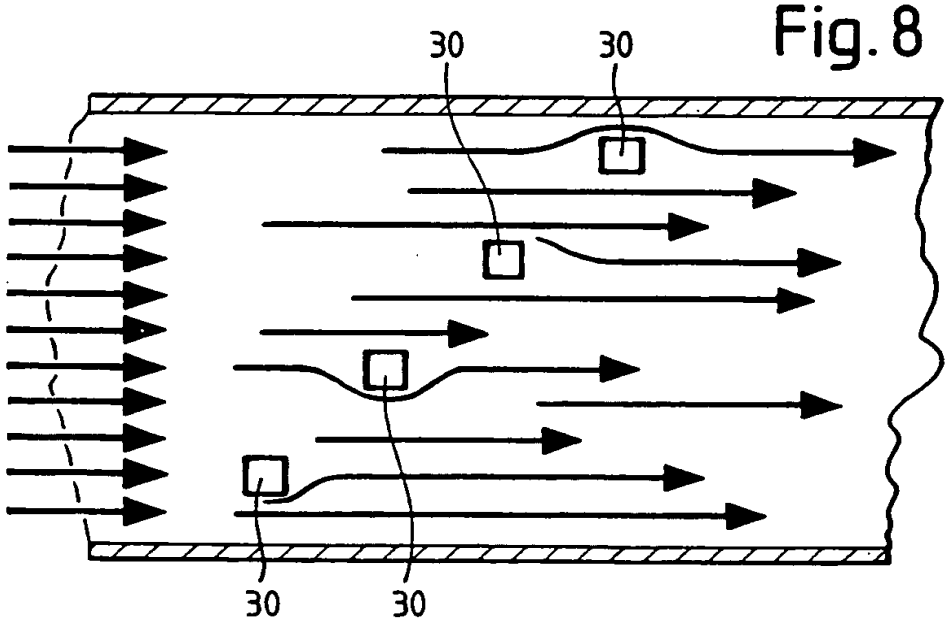


Fig. 7

Fig. 8



INTERNATIONAL SEARCH REPORT

Intern ial Application No
PCT/GB 00/02152

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28F1/42

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 012, no. 218 (M-711), 22 June 1988 (1988-06-22) -& JP 63 017393 A (NIPPON DENSO CO LTD), 25 January 1988 (1988-01-25) abstract page 455, column 1, line 30 - line 37; figures	1-5,9, 10,12,13
X	WO 98 44305 A (CREARE INC) 8 October 1998 (1998-10-08) page 18, line 14 - line 23; figures	14,15
A	US 5 730 213 A (KISER CARL E ET AL) 24 March 1998 (1998-03-24) column 4, line 19 -column 5, line 11; figures 4-9	1-13

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2000	22/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mootz, F

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INTERNATIONAL SEARCH REPORT

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PCT/GB 00/02152

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 165 583 A (HITACHI LTD ;HITACHI CABLE (JP)) 27 December 1985 (1985-12-27) abstract; claims 1-3; figures	1-13
A	US 4 470 452 A (RHODES EUGENE E) 11 September 1984 (1984-09-11) cited in the application abstract; figures	1-13
A	DE 295 09 684 U (BBK BLECHBEARBEITUNG & KOMPONE) 9 November 1995 (1995-11-09) page 6; figures	1-13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern. ...nal Application No
PCT/GB 00/02152

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 63017393 A	25-01-1988	NONE	
WO 9844305 A	08-10-1998	NONE	
US 5730213 A	24-03-1998	BR 9605545 A	18-08-1998
EP 0165583 A	27-12-1985	JP 1982731 C	25-10-1995
		JP 6100432 B	12-12-1994
		JP 61006595 A	13-01-1986
		DE 3570916 D	13-07-1989
		KR 9004811 B	07-07-1990
		US 4690211 A	01-09-1987
		US 4794775 A	03-01-1989
US 4470452 A	11-09-1984	CA 1192182 A	20-08-1985
DE 29509684 U	09-11-1995	NONE	